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WATER QUALITY CONTROL STUDY, LITTLE SIOUX RIVER BASIN, IOWA: STUDY OF THE NEEDS AND VALUE OF STORAGE FOR WATER QUALITY CONTROL

Federal Water Pollution Control Administration
Kansas City, Missouri

June 1967

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WATER QUALITY CONTROL STUDY
LITTLE SIOUX RIVER BASIN
IOWA

Study of the Needs and Value of Storage for Water Quality Control

UNITED STATES
DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Kansas City, Missouri

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WATER QUALITY CONTROL STUDY

LITTLE SIOUX RIVER BASIN

IOWA

ABSTRACT

A survey has been made which discloses immediate and future needs for storage for streamflow regulation for the purpose of water quality control. Future needs are based on results of economic and demographic studies projecting population and industrial growth.

Prepared for

DEPARTMENT OF THE ARMY

U.S. Army Engineer District

Omaha, Nebraska

June 1967

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I. INTRODUCTION

Authority

The Corps of Engineers, U.S. Army Engineering District, Omaha, Nebraska, in a letter dated January 25, 1967, requested the Federal Water Pollution Control Administration, the Missouri Basin Region, Kansas City, Missouri, to make a study of water quality control needs in the Little Sioux River Basin in connection with proposed reservoirs. This study has been made in accordance with provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.).

Purpose and Scope

The purpose of this study was to determine present and future needs and value of storage and water quality control in the Little Sioux River in the reaches affected by the proposed reservoirs. The study area includes parts of Cherokee, Woodbury, Ida and Monona counties in Iowa.

The dilution requirements and the means and benefits (both tangible and intangible) of meeting these requirements have been investigated. The scope of the study covers water storage needs during a one-hundred year study period, 1970-2070. The conclusions presented are tentative, pending completion of the Federal Water Pollution Control Administration's Missouri-Souris-Red River Basin Comprehensive Water Pollution Control Project. The water quality flow requirements and values as presented are suitable for project feasibility determinations.

Acknowledgments

The assistance and cooperation of State and Federal agencies and individuals are gratefully acknowledged by the Federal Water Pollution Control Administration. Particular appreciation is expressed to the following for data and advice furnished by their staff members.

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Iowa Natural Resources Council
Des Moines, Iowa

Iowa State University
Department of Economics and Sociology
Ames, Iowa

United States Geological Survey
Iowa City, Iowa

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Findings

1. The U.S. Army Corps of Engineers, Omaha District, is investigating the feasibility of various reservoirs in the Little Sioux River Basin. Primary purposes of the reservoirs are flood protection, recreation, municipal and industrial water supply, stream flow regulation and quality control.

2. This study encompasses only that area in the Little Sioux Basin which lies downstream from the proposed reservoirs.

3. The largest community in the basin and the only one requiring low flow augmentation is Cherokee, Iowa, which had a 1960 population of 7,724. The population of the economic area was 61,473 in 1960 of which 11,731 were urban and 49,742 were rural.

4. Essentially all communities in the study area with sewage collection systems provide secondary treatment. The exceptions are Correctionville, with primary treatment, and Danbury with no treatment. Wastes having a population equivalent of 700 and 500 respectively enter the stream at these communities.

Conclusions

1. The total population of the study area is projected to decrease from 61,473 persons in 1960 to about 46,000 by 2020 and then a slight increase is expected to about 51,000 persons by 2070. The rural population is expected to decrease from 49,742 in 1960 to about 29,000 persons in 2020 and to about 25,000 by 2070.

2. A draft-on-storage* of 20,000 acre-feet at a reservoir site on the Little Sioux River immediately above Cherokee is recommended for water quality control by the year 2070. This storage is needed in addition to provisions of adequate treatment at the source. The year of first need for releases for quality control is 1970.

3. Maintenance of satisfactory water quality by stream flow regulation in the Little Sioux River will give wide-spread benefit for recreational use and aesthetic enjoyment of the stream.

4. The annual value of the benefits resulting from storage in the proposed reservoirs above Cherokee to give a 90 percent yearly assurance that water quality will be maintained in 2070 is based on the best feasible alternative available. This was determined to be holding ponds which yield an annual benefit based upon the cost of construction and operation of $20,400 per year.

5. Because of the frequent observation that water from the lower depths of a reservoir is devoid of dissolved oxygen during certain times of the year, provisions should be made for the installation of multiple level outlet structures or for other means of assuring that releases of water of satisfactory quality. Actual releases should be based on waste discharges and observations of stream conditions.

*In this report the terms draft-on-storage and supplemental flow in volume are synonymous.

III. PROJECT DESCRIPTION

The proposed reservoirs, as shown in Figure 1 at the back of the report, are located in northwest Iowa in the lower reaches of the Little Sioux River, Maple River and West Branch. The sites on the Little Sioux and Maple Rivers are located above the principle municipalities, thus allowing for the use of storage to supplement low flows for water quality.

These proposed reservoirs are being investigated to determine their feasibility for multi-purpose uses such as flood and sediment control, conservation storage for recreation, fish and wildlife, water quality control, and urban water supplies. The locations, drainage areas contributing to the dam, and approximate storage volumes are given in Table III-1.

TABLE III-1

PROPOSED DAMS

Location	Drainage Area (Square Miles)	Storage Volume (Acre-Feet)
On Maple River, approximately one mile north of Ida Grove, Iowa	362	153,200
On Battle Creek, three miles north of Battle Creek, Iowa	49	22,500
On Moorhead Creek, about one-half mile south and three miles west of Battle Creek, Iowa	16	7,610
On Raynolds Creek, about one and one-half miles west and one mile north of Danbury, Iowa	19	9,240
On Elliott Creek, one-half mile northeast of Bronson, Iowa	61	25,600
On Mill Creek, about one mile north of Cherokee, Iowa	283	118,800
On Little Sioux River, about four miles north and one mile east of Cherokee, Iowa	1,300	496,700

IV. STUDY AREA DESCRIPTION

Location and Boundaries

The area considered in this report constitutes only part of the Little Sioux River Basin. The study area is limited to that area affected by the proposed reservoirs which includes the Little Sioux River from Cherokee to the mouth, the Maple River from Ida Grove to its confluence with the Little Sioux River and the West Branch from Bronson to the juncture with the Little Sioux River. The total drainage area of the basin is 4,507 square miles. The largest tributary is the Maple River with an area of 746 square miles. The topography of the study area is characterized by glacial deposits covered with wind-blown loess deposition. These wind-blown deposits are from 200 to 600 inches in depth and are quite susceptible to erosion. The slope of the stream channel is moderate to low. The channel is of the meandering type with many oxbows and pools.

Climate

The average normal annual precipitation in the basin is approximately 28.5 inches per year. Heavy rainfalls do occur, resulting in large runoff and excessive erosion.

The average temperatures in the basin from May to October are greater than 60°F. The daily average temperatures are less than 40°F from November to May. The magnitude of the temperature and its fluctuation has a definite effect on monthly dilution requirements. An analysis of the daily variation for July and August was made. The minimum and maximum temperatures for July

were 67°F and 83°F, respectively. The standard deviation was of a magnitude of approximately 3°F. Therefore, even though the extreme temperatures are quite far apart, the daily temperatures group quite closely around the mean. For the purpose of this study, it is sufficient to use average monthly temperatures since the daily variation is of a low magnitude.

Principal Cities and Industries

The principal cities in the study area are Cherokee, Ida Grove, and Mapleton. The largest of the principal cities studies is Cherokee, with a 1960 population of 7,724. The only waste producing industry which is of any magnitude in the basin is meat processing at Cherokee, Iowa.

V. WATER RESOURCES OF THE STUDY AREA

Quantity

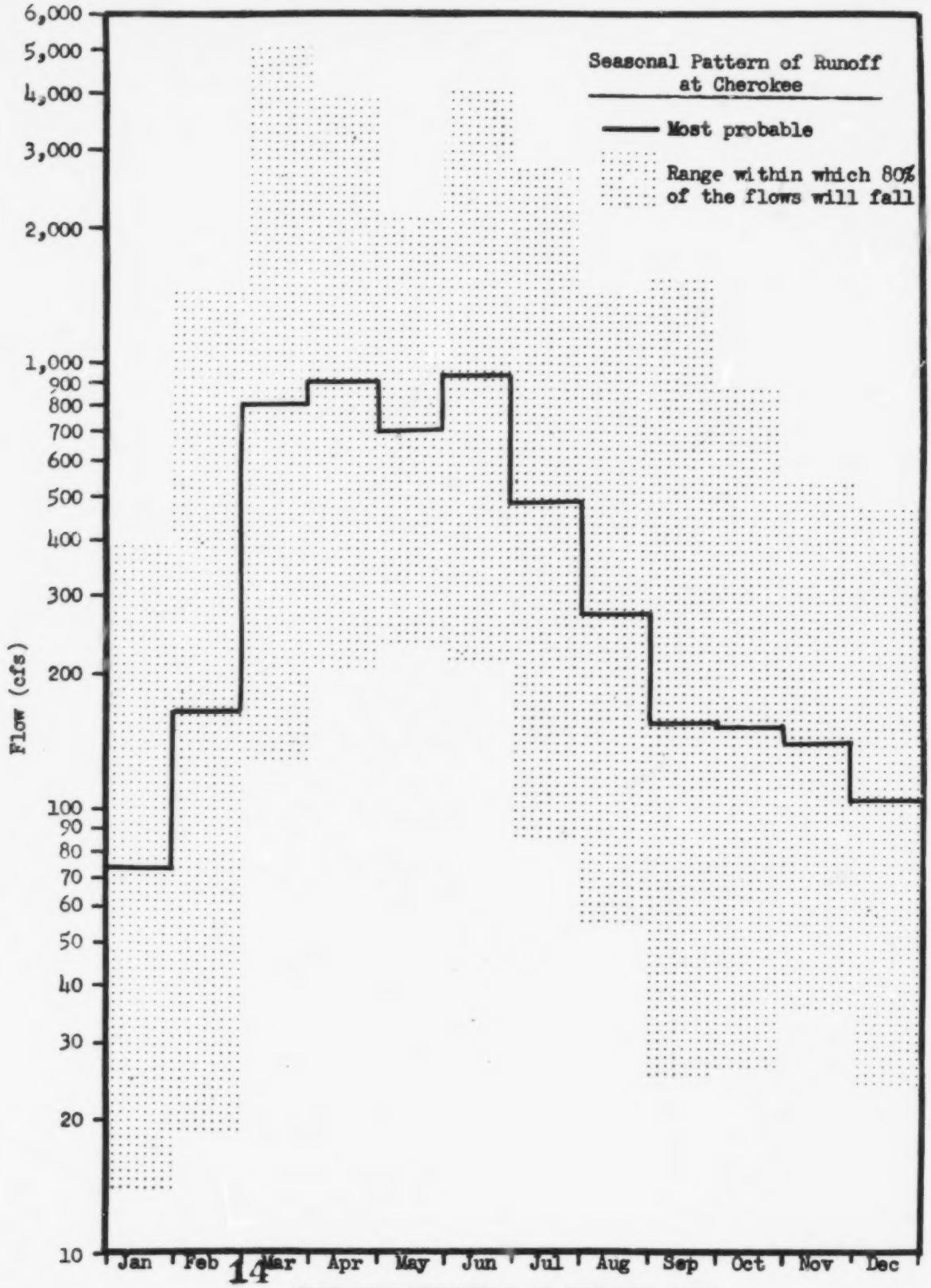
At the present time all the runoff in the basin is uncontrolled. The mean monthly streamflows at Cherokee are shown in Table V-1. Also shown is the standard deviation of the flow. As can be seen from the large standard deviations, the flow is highly variable.

Table V-1

Mean Flow and Standard Deviation of the Flows at Cherokee, Iowa - Historical Record of 29 Years

Months	Mean (cfs)	Standard Deviation (cfs)	Month	Mean (cfs)	Standard Deviation (cfs)
Jan.	79	73	July	608	597
Feb.	295	374	Aug.	350	361
Mar.	811	604	Sept.	333	516
Apr.	1023	1288	Oct.	174	174
May	665	511	Nov.	148	122
Jun.	940	853	Dec.	106	89

Figure 2 presents the results of an analysis of the streamflow records using logarithmic probability paper as recorded. As can be noted, the average flow in the months of March through June is quite high as compared with the other months of the year. The Figures and Table presented above were obtained by the use of data from the Correctionville, Iowa



FLOW CHARACTERISTICS AT CHEROKEE, IOWA

FIGURE 2

gaging station. The characteristics of the flows in the Maple River, as reported by the gaging station at Mapleton, are shown in Table V-2. Table V-2 also shows the average monthly flows at Ida Grove, Iowa. These flows were also determined from the gaging station at Mapleton. Also shown is the amount of flow which will be exceeded 90 percent of the time. For example, at Ida Grove in the month of January, 90 percent of the years the flow will be 9 cfs or greater.

Quality

No data are available on the chemical quality of the water of the Little Sioux River. No nuisance from adverse chemical quality is known, thus the necessity of investigating these parameters of quality has not occurred. Due to the type of soil and other characteristics of the basin, as formerly outlined, the possibility of the waters having a very high content of the metal, sulfate, or cloride ions is quite remote.

The hardness may run as high as 300 milligrams per liter (mg/l) to 400 mg/l as $CaCO_3$ by comparison with data from other rivers in the area.

The amount of sediment in the river has been a problem in relation to developing full potential as a fish habitat.[6/] This condition is not readily relieved by low flow augmentation. Proper soil conservation practices are necessary and a discussion of these is beyond the scope of this report.

TABLE V-2

FLOW CHARACTERISTICS OF MAPLETON AND IDA GROVE

	Mapleton		Ida Grove	
	Average	Flow Exceeded 90% of the Time	Average	Flow Exceeded 90% of the Time
Jan.	89	14	58	9
Feb.	55	16	36	10
March	310	50	200	34
April	180	42	120	27
May	240	60	160	39
June	420	84	270	55
July	210	68	140	44
Aug.	130	30	83	19
Sept.	92	24	60	14
Oct.	68	18	44	12
Nov.	62	21	41	14
Dec.	51	14	33	9

VI. ECONOMY

General

The purpose of this section is to present economic and demographic data to be used as a basis for estimating the future amounts and types of waste that may be expected to occur in the Little Sioux River Basin.

Economic data was gathered and analyzed in four counties in the Little Sioux River Basin. The study area consisted of the following counties: Cherokee, Ida, Monona and Woodbury (less Sioux City).

Past and Present

The Little Sioux River Basin has been an agrarian area. In 1960, 81 percent of the total population (61,473) of the study area lived in rural areas. The following table summarizes the population data:

TABLE VI-1

HISTORICAL POPULATION DATA
LITTLE SIOUX RIVER BASIN
1950-1960

Population	1940	Percent	1950	Percent	1960	Percent
Urban	10,907	15.6	11,203	17.0	11,731	19.1
Rural	58,899	84.4	54,775	83.0	49,742	80.9
Total	69,806	100.0	65,978	100.0	61,473	100.0

The population of the study area has been decreasing. In 1940, total population was 69,806; by 1950, population had decreased 5.5 percent to 65,978 and by 1960, population had decreased 6.8 percent to 61,473.[1/] From 1940 to 1960, population of the study area decreased 12 percent. Refer to Table VI-1 for details.

The population decrease of the study area was a result of the decrease in the rural population. The study area has one major urban center - Cherokee, with 7,724 persons in 1960.[1/] The urban population increase (annual rate 0.36 percent between 1940-60) was slower than the rural population decrease (annual rate 0.71 percent between 1940-60). The result has been a general decrease in population.

Thirty-four percent of the total labor force in the study area was employed in agriculture in 1960. Table VI-2 presents employment in the study area in 1960.

TABLE VI-2[2/]

1960 EMPLOYMENT DATA
LITTLE SIOUX RIVER BASIN

	1960	Present
Agriculture	7,149	34
Mining	30	--
Manufacturing	1,310	6
Total Basic	8,489	40
Total Service	12,093	57
Unemployed	682	3
TOTAL LABOR FORCE	21,264	100

In 1960, 633 people were employed in the manufacturing segment of food and kindred products.[2/] Most of these 633 were employed in the meat packing industry, a major water user and waste water contributor. The meat packing industry in the study area is centered in Cherokee, Iowa. Cherokee is the major source of water pollution in the Little Sioux River Basin having a population of 7,724 in 1960 with the meat packing industry. Other manufacturing industries in the study area are insignificant.

Irrigation is not a prime factor for agricultural production. Annual rainfall usually provides sufficient moisture for crops, so irrigation is necessary only in dry years or as a supplement to normal rainfall. Livestock and livestock products account for about 80 percent of the value of farm products sold.[3/] Refer to Table VI-3 for agricultural data.

TABLE VI-3

AGRICULTURAL DATA 1959, 1964*
IN MILLIONS OF 1959 DOLLARS
LITTLE SIOUX RIVER BASIN

	1959	1964*
Value of Crops sold	24.7	31.9
Value of Livestock and Livestock Products	94.8	103.5
Total Value of Farm Products Sold	119.5	135.4

*1964 Preliminary Data

Mining has a minor role in the economy of the study area.

Service and trade industries use small amounts of water and add small amounts of pollution.

Future

The meat packing industry will have the greatest demand for water, and will be the greatest deterrent to water quality in the study area through 2070. All production increases are projected to be in the Cherokee area. Using an index of future beef production requirements and the present slaughter capability, the following cattle slaughter is projected in the study area.

TABLE VI-4

LITTLE SIOUX RIVER BASIN
CATTLE SLAUGHTER 1960-2070

	1959-61 Average	1970	2020	2070
Million Lbs. Carcass Wt.	115.6	153.7	375.7	578.0
Index 4/	100	133	325	500

There will be a concomitant increase in pork production requirements. Using an index of future pork production requirements and the present slaughter capability, the following hog slaughter is projected in the study area.

TABLE VI-5

LITTLE SIOUX RIVER BASIN
HOG SLAUGHTER 1960-2070

	1959-61 Average	1970	2020	2070
Million Lbs. Carcass Wt.	110.4	120.3	250.6	375.4
Index	100	109	227	340

Cattle and hog slaughter operations are locating close to the supply of animals for slaughter. This decentralization of slaughter operations away from terminal markets is the latest trend in the marketing of meat products. 5/ This trend, by attracting new packing plants to the area, may be to the advantage of the study area.

The population of the study area is expected to decline through 1970, and then level off before slight population increases occur from 2020 to 2070.

Agriculture will continue to be significant to the economy of the study area through 2070. Continued emphasis will be placed on production of animals for slaughter.

Except for the meat packing industry, manufacturing and mining will have an insignificant role in the study area throughout the projection period.

The service and trade industries are expected to have slow growth in the study area through 2070.

VII. WATER QUALITY CONTROL

General

The use of water for municipal and industrial purposes will inevitably result in the production of liquid waste which, even after provision of levels of treatment considered adequate at this time, could degrade the quality of the receiving stream. It is essential that recognition be given to the facilities needed if the quality of the receiving streams is to be kept at acceptable levels. The potential of streamflow regulation to meet this need has been recognized in provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.) requiring consideration of the inclusion of storage in Federal Reservoirs for regulation of streamflow for water quality control in the survey or planning of a reservoir by any Federal agency. Section 3b of the Act expressly states that any such storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling wastes at their sources.

Municipal and Industrial Pollution

The municipalities considered in this study, which have public sewer systems and discharge effluent into the streams in the basin are shown in Appendix I at the end of this report. The methodology used in determining the needs is shown in Appendix 2. As mentioned before, the major industry within the basin is meat processing. The waste from this industry is high in organic pollution.

Another source of organic pollution can be agriculture, especially the feeding of cattle on concentrated feedlots. This situation has not been and is presently not a problem in the area under study. The possibility for future developments of pollution problems from this source would seem remote. The Iowa State Department of Health is studying the problem and can be expected to enact legislation which will control the runoff such that it will not produce a serious stream pollution problem.

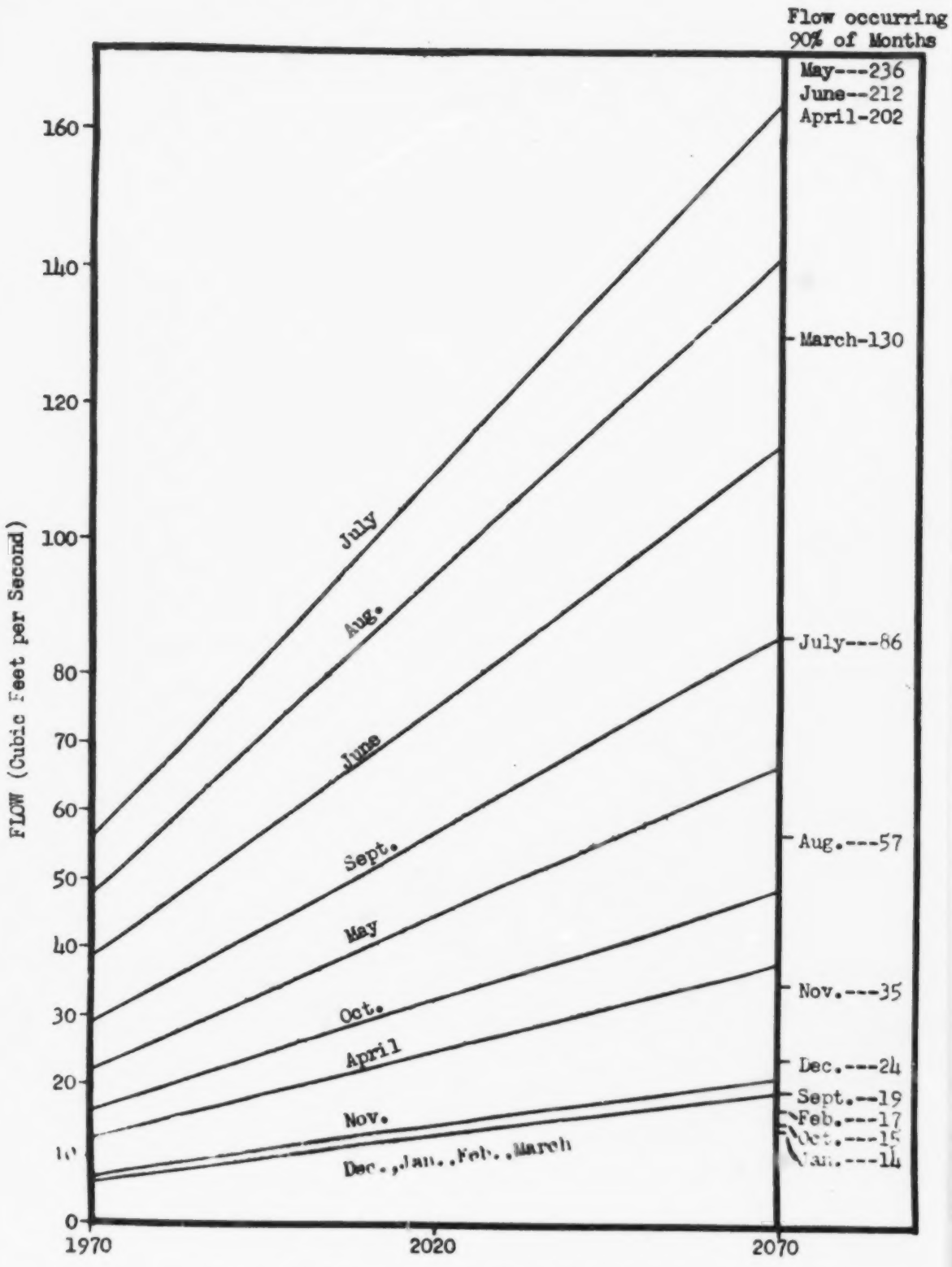
Water Quality Criteria

Surface runoff and water discharged from underground sources which appear as streamflow serves many useful functions. Some of these are: Supplying water for human consumption; for agricultural uses; for industrial operations; for cooling purposes; for generating hydro-electric power; and for recreational purposes. Because of this great variety of possible uses, available streamflow supplies must maintain quality as demanded by these uses. The overriding quality demand as far as dilution requirements are concerned in the Little Sioux River is in connection with dissolved oxygen concentration. It has been demonstrated that a dissolved oxygen concentration of 5 mg/l is needed for the optimum growth of fish life. This criterion is generally accepted by most governmental and other water pollution control and conservation agencies The present major species of fish in the upper and middle reaches of the Little Sioux River is catfish. In the lower reaches the stream becomes heavily silted, which combined with extensive channel straightening, has made the stream uninhabitable for any but the most tolerant of species. As noted in the description of the study area, the river traverses topography made of a loess mantle which is subject to erosion, thus causing the heavy sediment concentration in the lower reaches. A combined program of soil conservation,

therefore, in addition to municipal and industrial waste treatment, is needed if the streams are to be able to maintain a fish population.

Flow Regulation

Provision for storage for streamflow regulation has been based on the provision of adequate treatment (as defined in Appendix 3) for all municipal and industrial waste. Analysis of the effects of the present and anticipated waste loads in the Little Sioux River indicates that the critical oxygen sag will occur immediately below Cherokee, Iowa. By maintaining the required flows at Cherokee, the water quality needs for all waste outlets below Cherokee are also satisfied. Figure 3 shows the amount of flow required to maintain 5 mg/l dissolved oxygen (D.O.) concentrations for the present and future projections, along with the amount of flow available for 90 percent of the months. Thus, in July, 90 percent of the time the flow is 86 cfs or larger and the present quality need is 56 cfs, therefore, no low flow augmentation benefit can be presently ascribed. However, by 2020, flow requirements for quality control will increase to 110 cfs, thus requiring low flow augmentation. Flow needs were analyzed, as noted, for each month. Most of the streamflow regulation for water quality control will occur during the summer and fall months. The values shown are minimum required streamflows above the sewage outlets from Cherokee and include natural runoff as well as reservoir releases. They are theoretical requirements and the actual regulation of flow must be based on adequate water quality monitoring. As the communities develop and additional waste loads are encountered, the dilution flow must be increased accordingly.



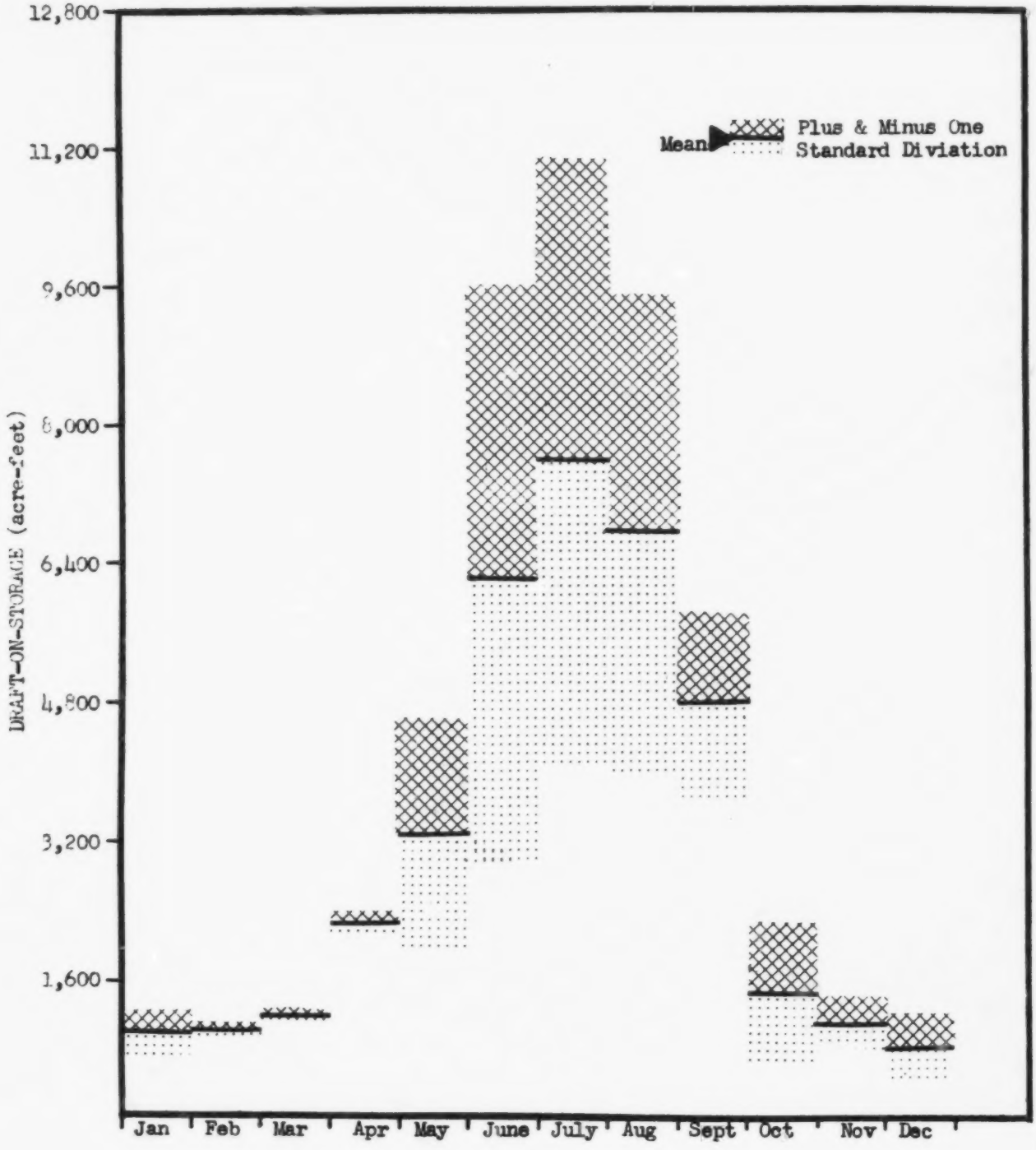
MONTHLY FLOW REQUIREMENTS TO MAINTAIN DESIRED QUALITY

An analysis of the dilution requirements on the Maple River indicate two oxygen sags which could occur. These sags could occur below Ida Grove and Mapleton. However, the dilution flow requirements needed to prevent the reduction of the D.O. to less than 5 mg/l at the critical point is very small compared to the natural flows available. The maximum flows required at Mapleton and Ida Grove are 2 cfs and 3 cfs, respectively. As can be seen, the natural flows are sufficient to prevent a D.O. below desirable levels.

Storage Requirements

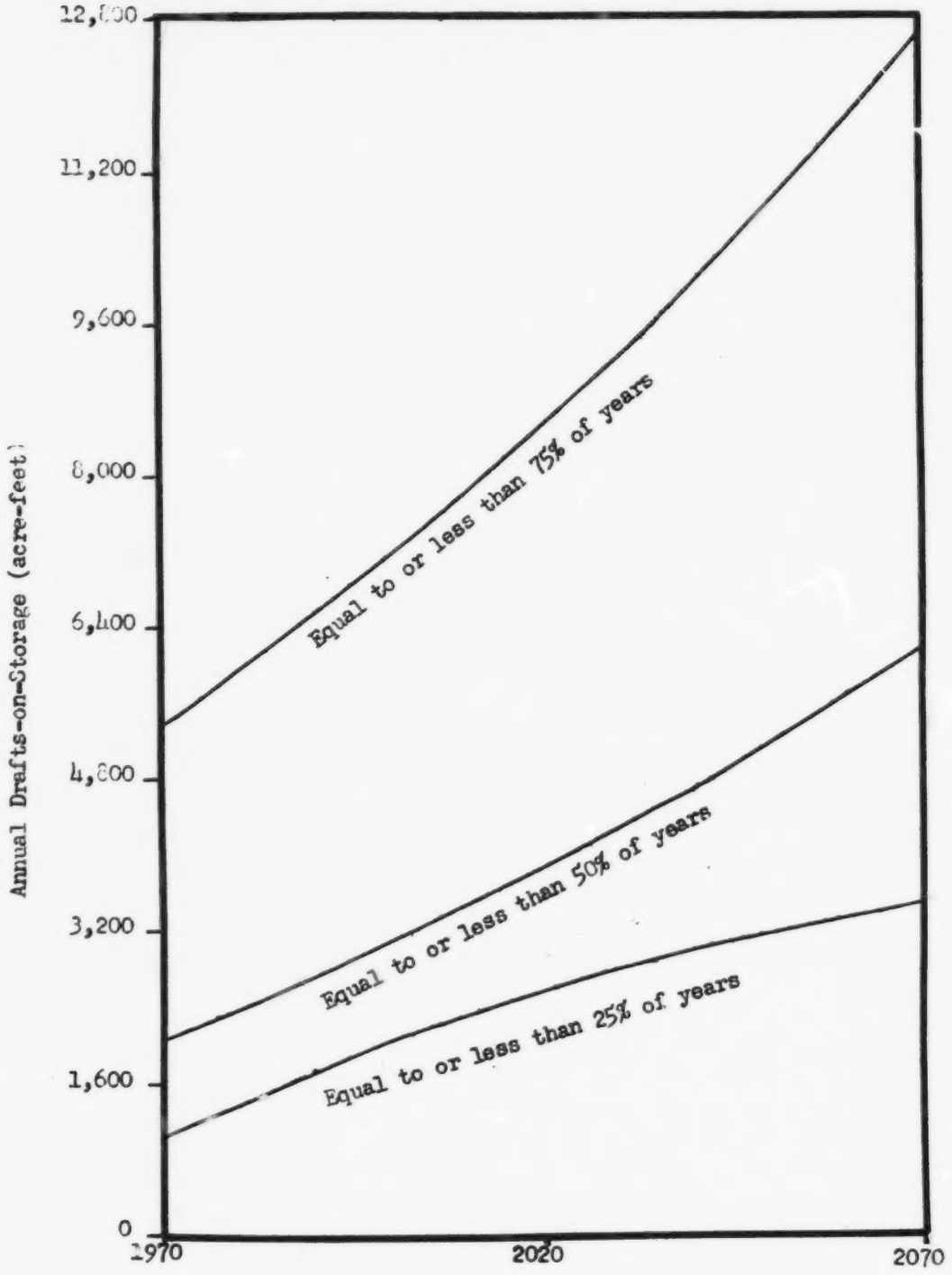
The required draft-on-storage was calculated by routing synthetically generated* monthly flows through a series of different sized reservoirs neglecting the effect of evaporation, sediment storage and reservoir management. This analysis is presented in Appendix 3 and a summary of the analysis is presented here. Figure 4 shows the drafts-on-storage required in 2070 for the recommended quality level for each month. The range of variation is shown by plus and minus one standard deviation. Therefore, 68 percent of the drafts required will fall within the range shown. Figure 5 shows a similar type of information, but in terms of percentage of years. Thus, for the year 2020, 25 percent of the years the draft is equal to or less than the 2120 acre-feet and for 50 percent of the years it is equal to or less than 3860 acre-feet. A total draft-

*Synthetic flows were generated based on analysis of the monthly flow records available on the Little Sioux River at Correctionville, Iowa, considering seasonal changes and serial correlation between succeeding seasons.



THEORETICAL MONTHLY DRAFTS-ON-STORAGE REQUIRED TO MAINTAIN DESIRED QUALITY IN YEAR 2070

FIGURE 4



PROBABILITY OF ANNUAL DRAFTS OF STORAGE TO MAINTAIN DESIRED QUALITY

FIGURE 5

on-storage of 20,000 acre-feet is recommended. This will provide a protection level of 90 percent of the years at the recommended quality of 5 mg/l D.O. concentration. In other words, a failure could occur in one year out of ten. The dashed lines in Figure 8, 9, and 10 in Appendix 3 indicate the relative position of this storage as it relates to water quality.

With storage for a supplemental flow of 20,000 acre-feet and routing 250 years of synthetically generated monthly flows, it was found that the most failures occur in the months of August through December. The average failure in these months for the year 2070 is given in Table VII-1.

TABLE VII-1

MONTHLY FAILURES

Months	Average Dilution Requirements - AcFt.	Average Failure (AcFt.)	Probability of Failure - %
August	8730	4017	2.0
September	5120	3318	4.8
October	3010	1387	1.6
November	1250	777	0.8
December	1170	978	1.2

As can be seen, the number of failures in September is more than double that for any other month. In the months that do fail, based upon the operation scheme used, the dissolved oxygen would go below that which

can be tolerated by fish life. Under actual reservoir operation, it would be possible to limit the releases in preceding months when reservoir levels were dangerously low and thus decrease the magnitude of failure. This would have the effect of increasing the number of failures. If, however, the quality was allowed to go from 5 mg/l to 4 mg/l D.O. in the fall, it would have little effect on the fish life.

If the magnitude of failures were averages over all months, they would average about 24 acre-feet per month in the year 2070, which would have negligible effect on water quality. However, as comparison, a storage of 18,000 acre-feet would result in a monthly failure of twice this or 48 acre-feet even though it only reduces the probability of assurance of maintaining 5 mg/l from 90 percent to 87 percent of the years.

Storage for water quality on the West Branch and Maple River, as has been pointed out before, is not required; therefore, no analysis of the effect of storage on water quality has been made for these streams.

In the design of outlet facilities on the proposed reservoirs, water intakes which would draw off near the upper reaches of the reservoir should be considered. During the summer months, stratification will occur with resulting low dissolved oxygen concentrations in the lower depths of the reservoirs. A study of the Coralville reservoir on the Iowa River in Iowa indicates that the oxygen content can drop down to between zero and 3 mg/l for long periods of time. Therefore, in order to meet this problem, it is recommended that an upper level intake or

some other means of drawing of the better quality water near the surface be provided. Mechanical aeration of discharged waters to assure uptake of oxygen to maintain at least 80 percent saturation is another solution.

VIII. BENEFITS

Water Quality

The benefits to be derived for storage from streamflow regulation for water quality control may be both tangible and intangible. Benefits that will result from storage in the proposed reservoirs above Cherokee are based on cost of the most feasible alternative that will achieve comparable results. The assured adequate water quality will provide favorable conditions for recrestion, such as fishing, for those living in the Little Sioux River Basin, and nearby areas. It is reasonable to anticipate that the total population in the study area, plus the people located in the Sioux City metropolitan area will be able to enjoy the recreational opportunities made possible by control of water quality.

In addition to recreational benefits, riparian property owners will enjoy improved esthetics of the stream stemming from unpolluted surface water and a satisfactory public health environment. From the above, it is concluded that benefits are widespread in scope and sufficient in magnitude to justify the provision of the volume of storage necessary for the required streamflow regulation. These benefits credited to storage for the regulation of stream flow for water quality control purposes are based on the premise that adequate treatment will be provided. Streamflow regulation for quality control, together with adequate treatment of municipal and industrial wastes, will maintain the desired oxygen concentrations which will benefit the fishery by providing an optimum environment for growth. If streamflow regulation is not provided as recommended, recreation will suffer. The critical areas in the river

will have periods of low oxygen content in which fish will not be able to survive even though waste treatment is provided to the fullest extent now practicable.

The actual value of the benefits derived are difficult to assess by a direct evaluation since they are of intangible nature. Therefore, in order to approximate the value, the cost of achieving the same results by the most likely alternative was used.

The most feasible alternative in achieving the desired quality was determined to be holding ponds. The total cost of sub-ponds is $500,000. The year of first need is 1970. The annual operation and maintenance cost is $4,000. With an interest rate of 3 1/8 percent and amortised over a one hundred year period, the annual value of storage for flow regulation for water quality control is $20,400.

BIBLIOGRAPHY

1. U.S. Bureau of Census, U.S. Census of Population, 1960, Volume I, "Number of Inhabitants," U.S. Government Printing Office, Washington, D.C. 1961.

2. U.S. Bureau of Census, U.S. Census of Population, 1960, Volume II, "Characteristics of the Population," U.S. Government Printing Office, Washington, D.C. 1962.

3. U.S. Bureau of Census, U.S. Census of Agriculture, 1959, 1964. Volume I, U.S. Government Printing Office, Washington, D.C., 1961, 1967.

4. Economic Research Service, Unpublished Data, U.S. Department of Agriculture.

5. Ives, J. Russell, Livestock and Meat Economy of the United States, 1966, American Meat Institute, Chicago, Illinois.

6. Iowa Natural Resource Council, An Inventory of Water Resources and Water Problems, Western Iowa River Basins, 1959 State House, Des Moines, Iowa.

7. Schwob, Harlan, H., Low-Flow Characteristics of Iowa Streams, 1959, Iowa Natural Resources Council, U.S. Geological Survey, Water Resources Division, Bulletin No. 9.

8. Larimer, O. J., Drainage Areas of Iowa Streams, 1957, U.S. Geological Survey, Water Resource Division, Bulletin No. 7.

Appendix 1

Municipalities with Sewage Treatment Systems in the Study Area

Community	1960 Population	Estimated Population Served	Discharge to	Type of Treatment	P.E. (BOD) Raw	P.E. (BOD) Discharged
Anthon	681	650	Little Sioux River	Secondary	650	400
Battle Creek	786	550	Maple River	Secondary	550	550
Cherokee	7,724	7,700	Little Sioux River	Secondary	9,200E	1,300E
Correctionville	912	900	Little Sioux River	Primary	1,000E	700E
Danbury	510	500	Maple River	None	500	500
Ida Grove	2,265	2,200	Maple River	Secondary	3,200	400E
Mapleton	1,686	1,400	Maple River	Secondary	2,200	700E
Onawa	3,176	3,000	Monona-Harrison Ditch	Secondary	3,210	480
Quimby	369	330	Little Sioux River	Secondary	330E	200E
Washta	310	300	Little Sioux River	Secondary	310E	200E

Appendix 2

Calculations for Water Quality Needs

The oxygen sag formula used to determine the pollution flow requirements to maintain specific levels of quality was the standard Phelps-Streeter formula. In using this algorithm, several parameters need to be known. These include deoxygenation and reaeration rates, initial saturation of dissolved oxygen, water temperature, and time of travel. For this study, field studies to determine the above parameters were beyond the scope of this report. Therefore, the values used were those of a typical stream of the type with which the study is concerned. A deoxygenation value of .1 at 20°C and a reaeration rate of .25 at 20°C were selected. These were modified to take into account the temperature variation by the equations $K_1 = K_{20}\ (1.047)^{T-20}$ and $K_2 = K_{20}\ (1.0159)^{T-20}$ for the deoxygenation rate and reaeration rate, respectively. The initial concentration of the dissolved oxygen of the dilution water was assumed to be 80 percent of maximum saturation and the concentration of the waste effluent to be 2 mg/l. The velocity of flow was estimated to be approximately 0.75 feet per second.

Due to the distance between waste outfalls, there was no carry-over of biological oxygen demand (BOD) from one municipality to another. The assimilation model indicated, when considering the location of the proposed reservoirs above Cherokee, Iowa, that the critical section of the river would be located a few miles below Cherokee. If this point is satisfied, the rest of the main stem of the Little Sioux River will also have satisfactory conditions. On the Maple River the main waste contributors

are Ida Grove and Mapleton. Both of these communities have proposed reservoir sites immediately above them. No low flow augmentation is required at these locations and, therefore, no further elaboration of the analysis for these areas will be given.

In the case of Cherokee, low flow augmentation is needed. The major volume of waste discharge to the river at Cherokee originates from the meat processing industry. This waste presently is being treated by a series of waste stabilization ponds. This type of waste is very concentrated, that is, it has a very high BOD demand. The present five day BOD concentration is approximately 1,300 miligrams per liter (mg/l), as compared with 200 mg/l from the City of Cherokee. In order to understand the need for low flow augmentation, one needs to analyze what the conditions would be if no low flow augmentation was provided. Figure 6 indicates the dissolved oxygen levels at different occurrence probabilities at the critical point if no low flow augmentation were provided and an 85 percent municipal reduction in BOD and 90 percent industrial reduction in BOD is obtained. The solid line indicates the present conditions, while the dashed lines are for conditions as projected to 2070. For example, in 2070 90 percent of the time in the month of September the quality will be equal to or better than 1 mg/l and 80 percent of the time it will be equal to or better than 4 mg/l. The quality for 80 percent of the months in 1970 and 50 percent of the months in 2070 is 6 mg/l or greater under natural conditions.

When calculating water quality needs, it is found that different quantities of dilution flow requirements will result by choosing different degrees of treatment of the raw sewage. This is especially true when the waste is of a high concentration such as a packing house waste. For example, if the effluent from the meat packing industry has a 10 percent residual the dilution flow requirements in order to maintain 5 mg/l of dissolved oxygen in the month of July under year 2070 conditions is 164 cubic feet per second. However, if the residual is reduced to 5 percent the dilution flow is reduced to 85 cubic feet per second or almost a factor of one half.

Public Law 660 provides that ". . . . storage and water releases shall not be provided as a substitute for adequate treatment or other means of controlling waste at the source." Quantities of water required for water quality control are computed on the premise that adequate treatment will be provided.

Based on organic removal obtained from well operated municipal biological sewage treatment plants, it is expected that 90 percent removal of biological oxygen demand (BOD) can be obtained for municipal wastes reaching the sewage treatment plant. At the present time, however, urban runoff will be expected to contain waste amounting to about 5 percent of the BOD found in municipal waste and is not generally amenable to economical treatment; therefore, adequate treatment for purposes of evaluation of storage needs is considered as 85 percent removal of BOD from the collected municipal wastes.

In the case of Cherokee, we also have the waste from the meat packing industry. This waste is amenable to biological sewage treatment. Many plants today are achieving a BOD removal of up to and even greater than 90 percent. Since plants are presently being constructed which will reduce the BOD by 90 percent and greater, and since the waste is of a uniform nature and amenable to biological treatment, for the purposes of this report adequate treatment for this industrial waste is defined to be a reduction of 90 percent. Using adequate treatment, as defined Figure 7 shows the relationship which exists between flow augmentation and dissolved oxygen at the critical point for the month of July. It can be seen that flow requirements to maintain different qualities increase at a uniform rate over the hundred year study period.

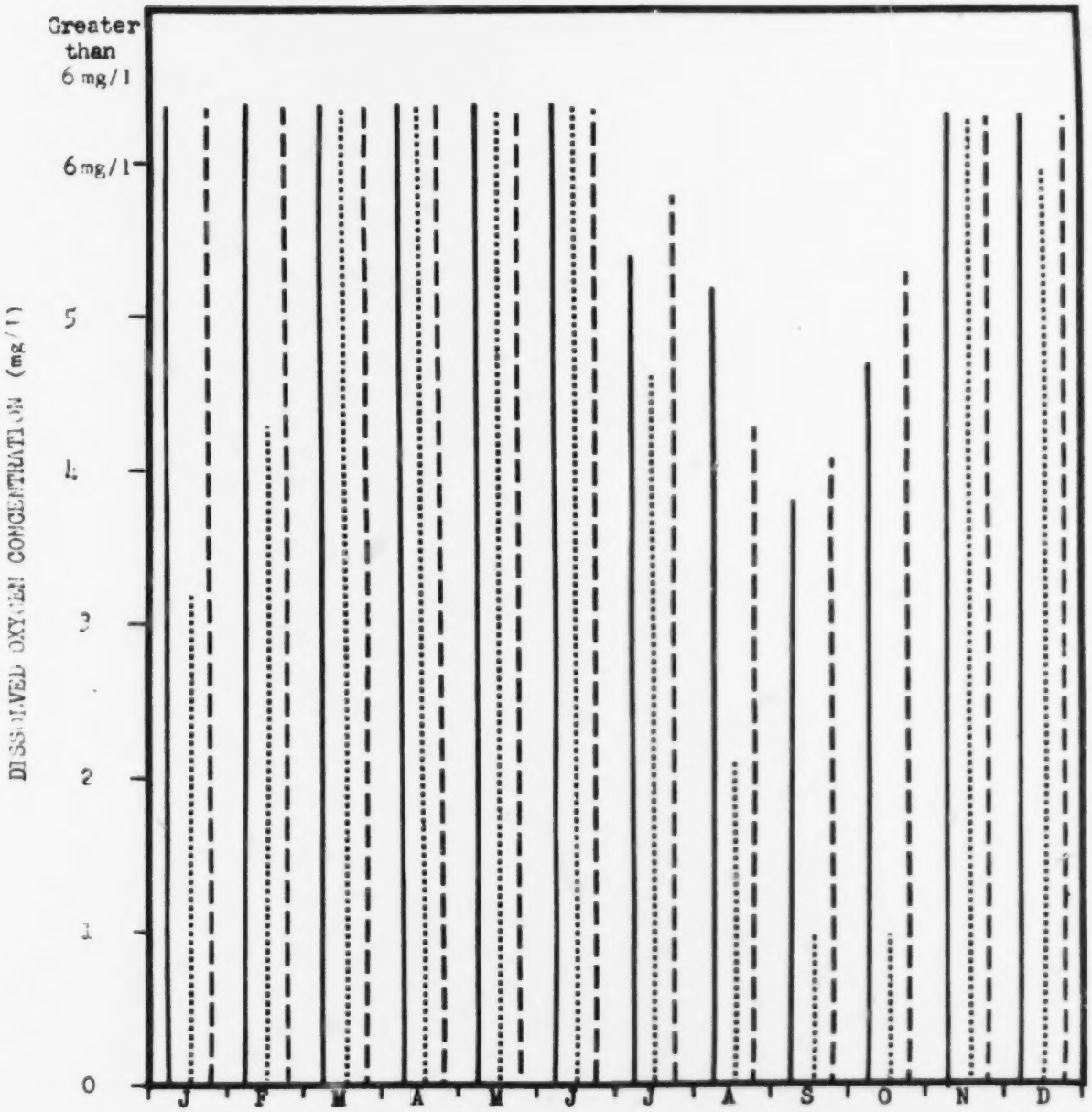
The flow requirements to maintain the higher dissolved oxygen concentrations increase more rapidly at the higher quality levels. For example, only 30 cfs more will increase the dissolved oxygen concentrations from 2 mg/l to 4 mg/l in the year 2020, and to go from 4 mg/l to 5 mg/l requires only 42 cfs more; but to go from 5 mg/l to 6 mg/l requires 143 cfs more. As can be seen, it requires about a doubling of the flow to gain very little increase in quality when a quality level of 5 mg/l is reached. Also shown on the graph by the dashed line is the flow which occurs 90 percent of the months and 80 percent of the months of July. Therefore, it can be seen that for most of the years without any flow augmentation a quality level of 4 mg/l can be maintained in the month of July.

LEGEND

——— Quality equal to or better than 90% of the month in 1970

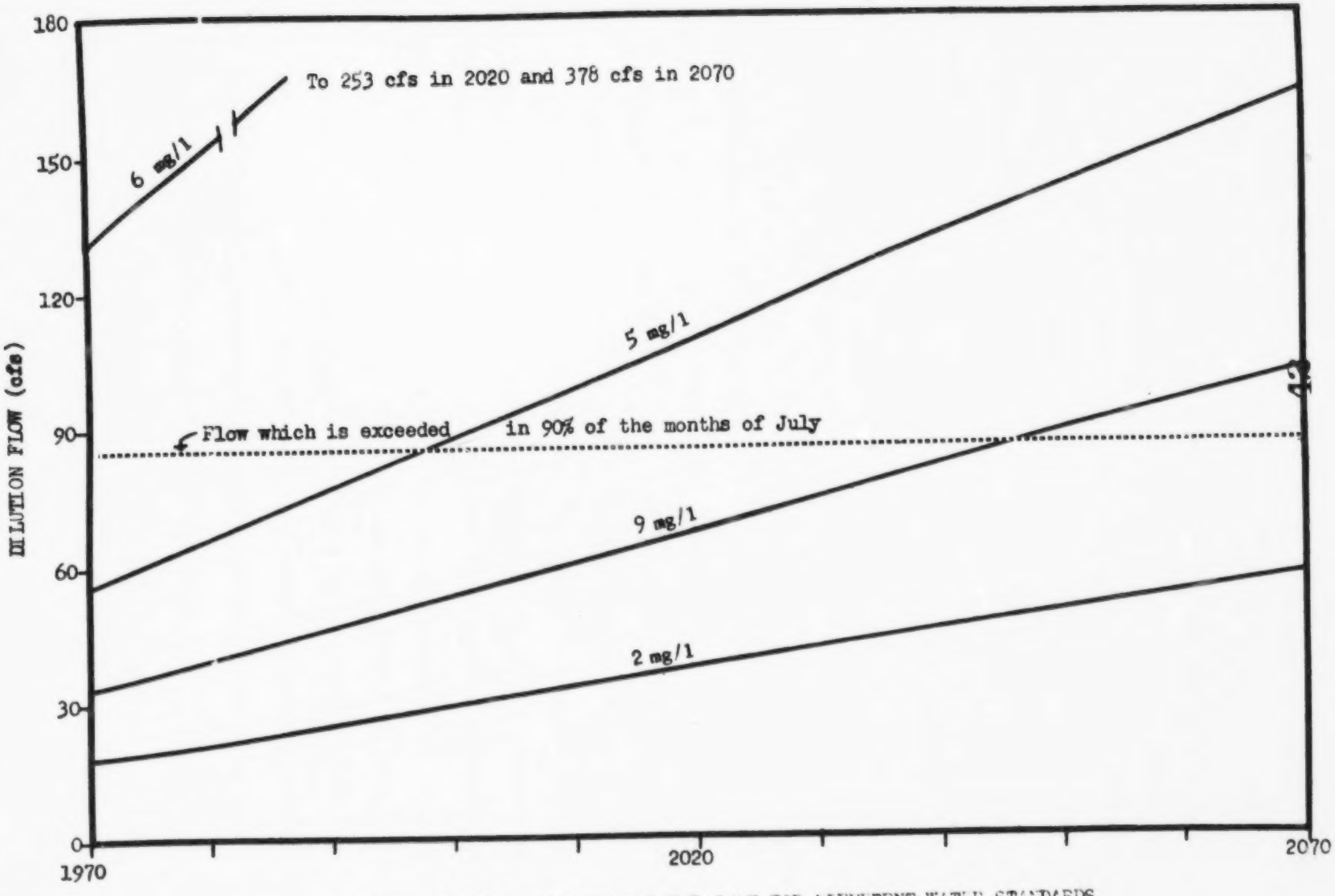
..... Quality equal to or better than 90% of the month in 2070

– – – – Quality equal to or better than 80% of the month in 2070



QUALITY EXPECTED WITHOUT LOW FLOW AUGMENTATION

FIGURE 6



DILUTION FLOW REQUIREMENTS FOR JULY FOR DIFFERENT WATER STANDARDS

FIGURE 7

Appendix III

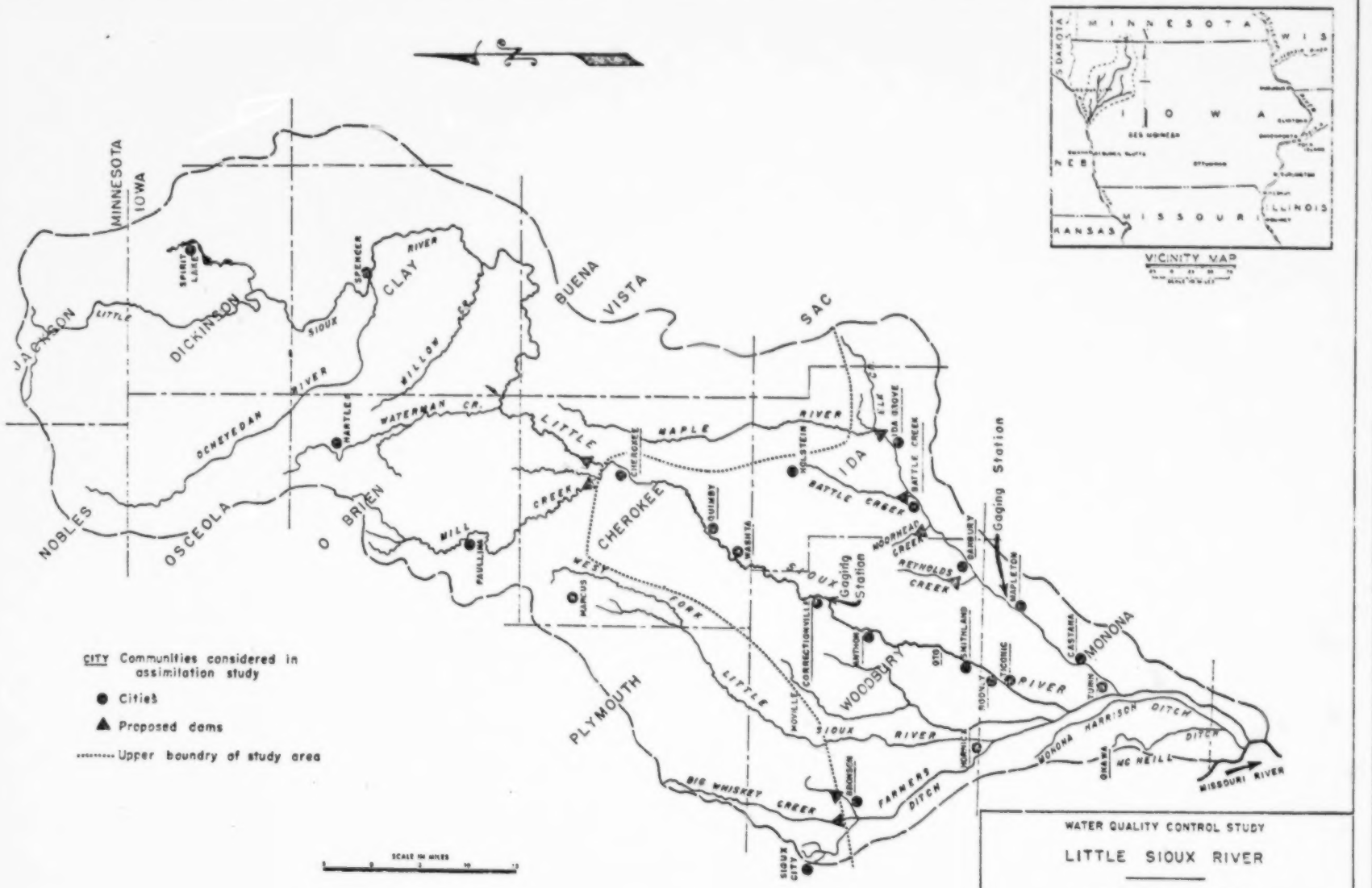
Effect of Storage on Water Quality

Relationships exist between water quality in a stream and quantities of storage in reservoirs on the stream. The presentation in this appendix will help to indicate the effect of storage on water quality.

The means required to insure against complete nonfailure of a stream standard would be extreme and impracticable. Therefore, when analyzing storage for water quality control it is necessary to think of it in terms of the probability of failure. Figures 8, 9, 10 show the relationship between supplemental flow in terms of volume and quality obtainable at different probabilities of failure. They are shown for conditions in the years 1970, 2020 and 2070. As an example, in the year 2020 a supplemental flow of 7,800 acre-feet will maintain a quality of 4 mg/l of dissolved oxygen for 90 percent of the years. By increasing the storage to 12,000 acre-feet a quality level of 5 mg/l can be maintained at the same probability level.

The amount of supplemental flow required will increase as the basin develops and waste loads increase. Figure 11 shows the effect of this future development on water quality storage requirements. This graph shows the storage necessary in order to maintain the given quality levels for 90 percent of the years. For example, a storage of 5,600 acre-feet in 1970 will maintain a quality level of 5 mg/l, however this increases to 20,000 acre-feet by the year 2070. As can be noted if a storage of only 5,600 acre-feet were provided which allows an attainment of 5 mg/l in 1970, by the year 2070 the quality will have dropped to 2 mg/l. However, the 5 mg/l dissolved oxygen concentration would still be attainable for 50 percent of the years as shown in Figure 10. Also shown in Figure 11

is the storage requirement that is needed to maintain a stream standard of 5 mg/l of dissolved oxygen with an assurance of 95 percent of the years and 80 percent of the years.



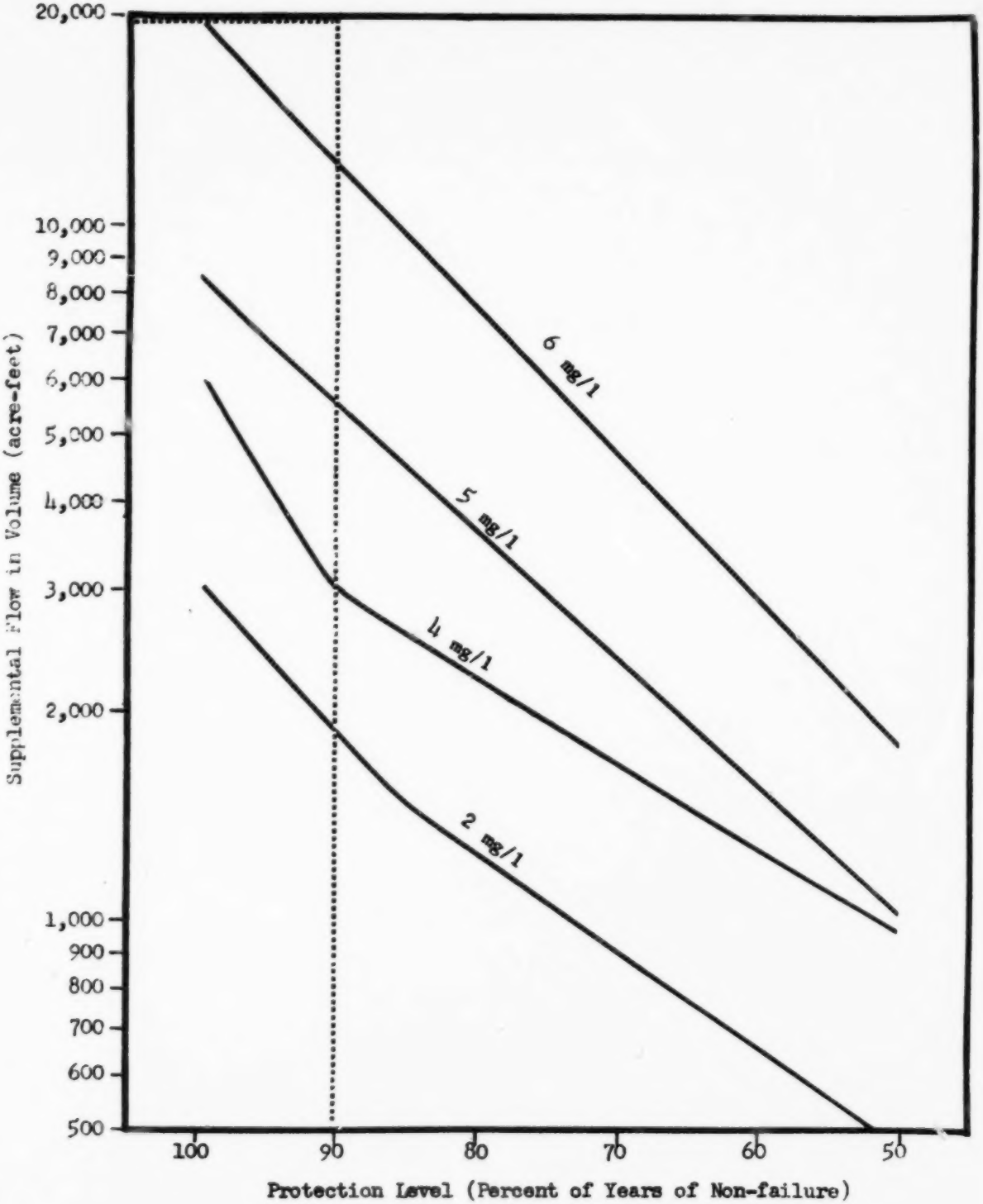
WATER QUALITY CONTROL STUDY

LITTLE SIOUX RIVER

LOCATION MAP

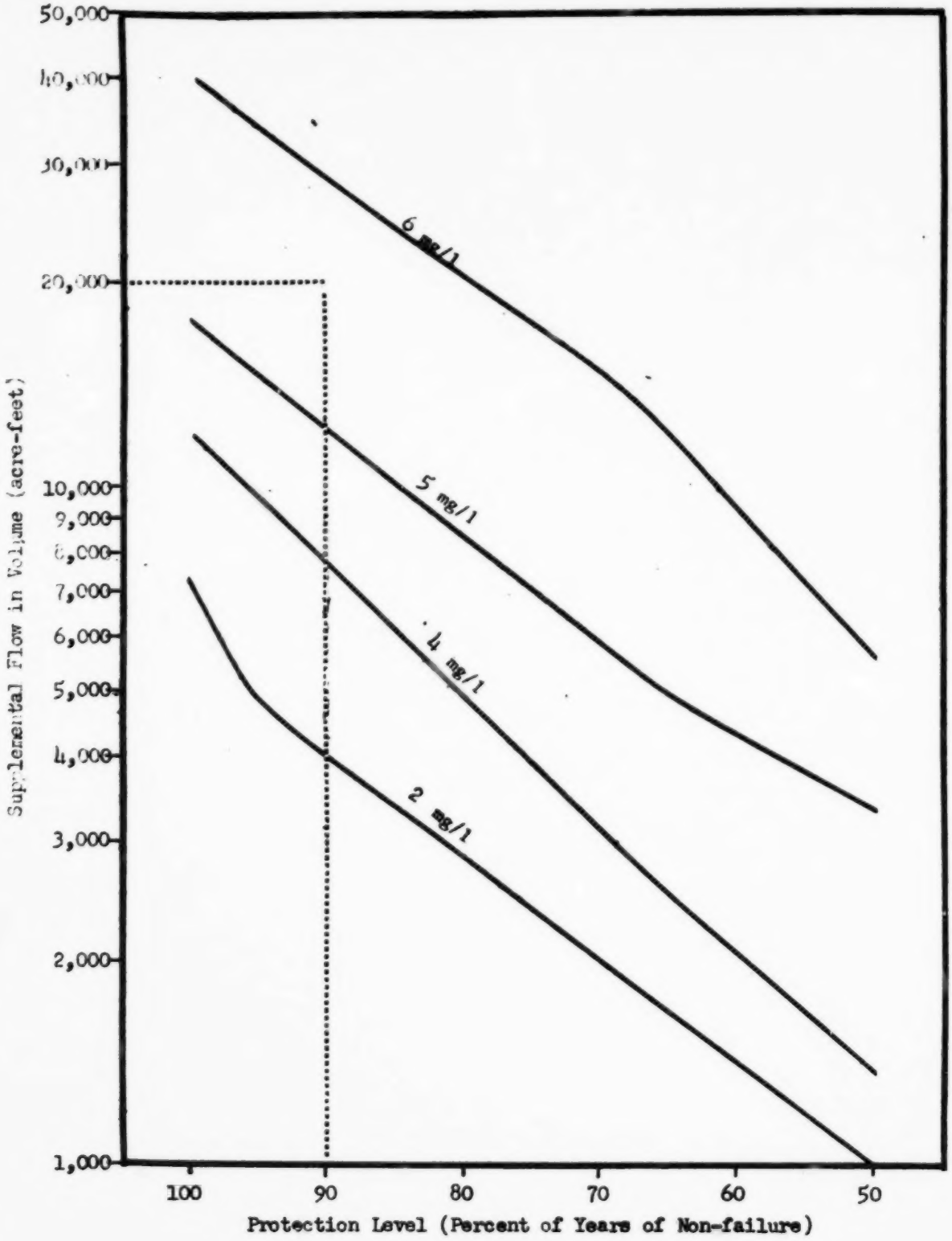
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
KANSAS CITY, MISSOURI

FIGURE 1



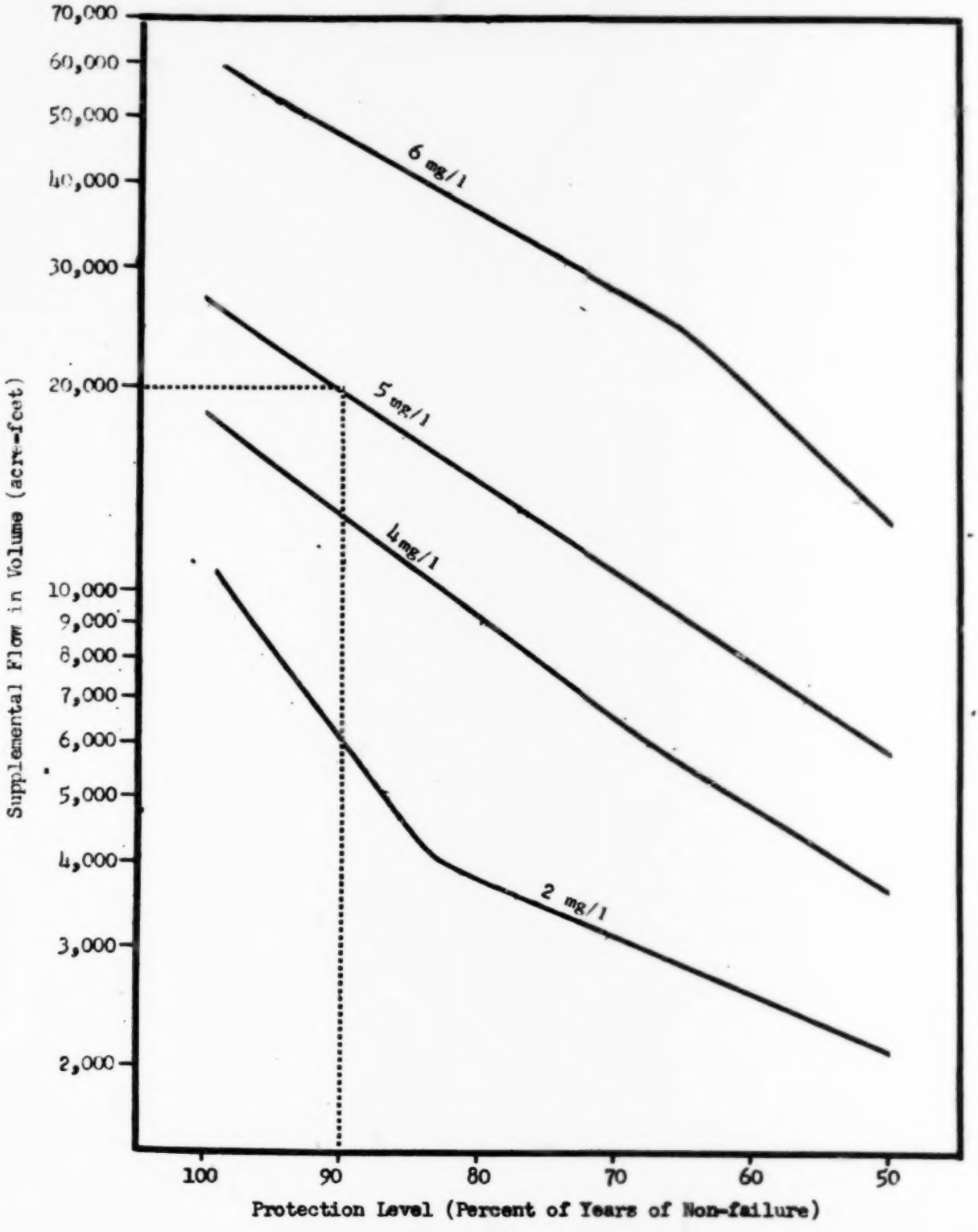
SUPPLEMENTAL FLOW REQUIRED VS PROTECTION LEVEL
YEAR 1970 CONDITIONS

FIGURE 8



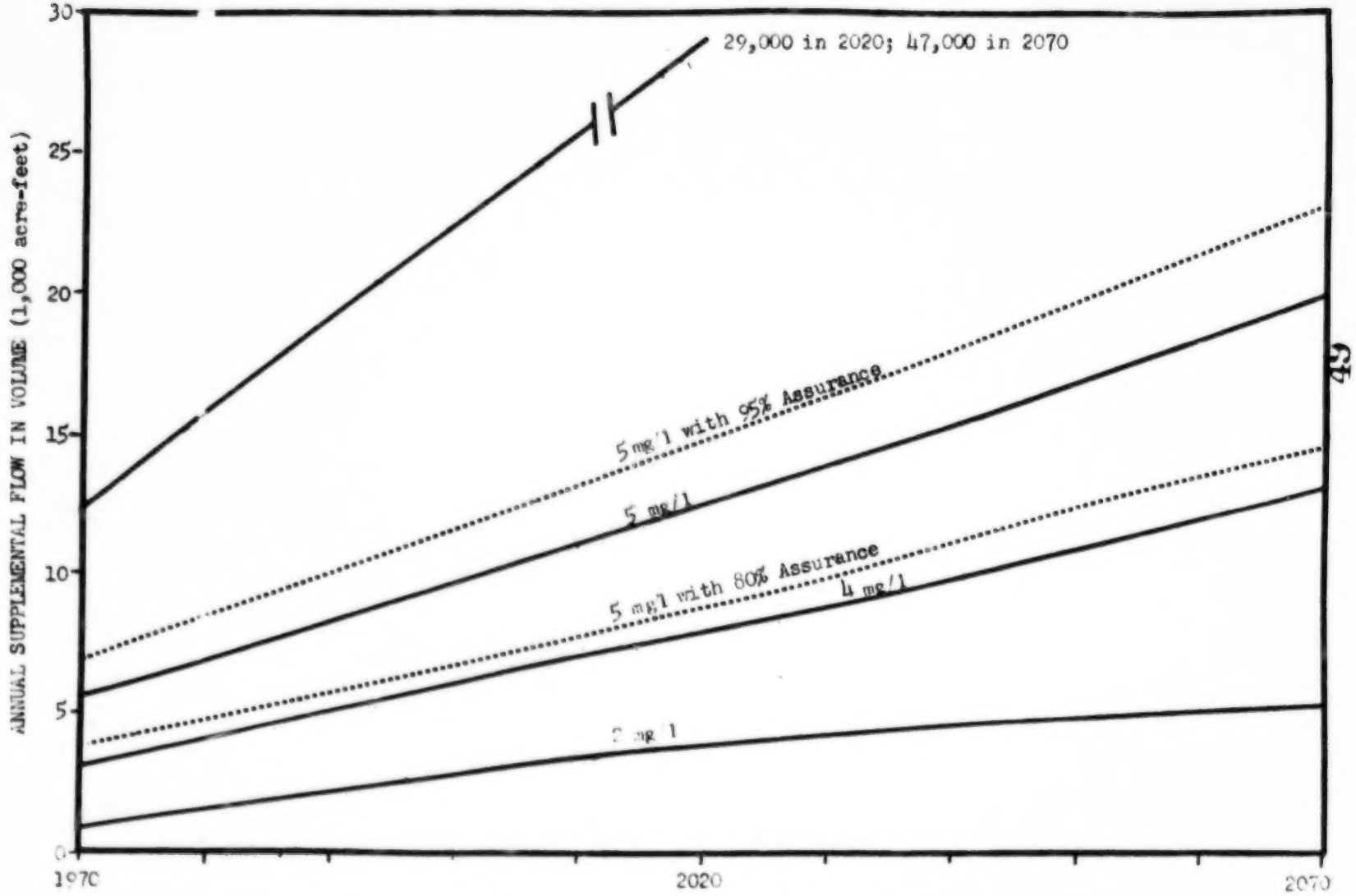
SUPPLEMENTAL FLOW REQUIRED VS PROTECTION LEVEL
YEAR 2020 CONDITIONS

FIGURE 9



SUPPLEMENTAL FLOW REQUIRED VS PROTECTION LEVEL
YEAR 2070 CONDITIONS

FIGURE 10



ANNUAL SUPPLEMENTAL FLOW IN VOLUME FOR A 90% PROBABILITY OF ASSURANCE

FIGURE 11